REISSUE SPECIFICATION

OPTICAL DISC RECORDING/ REPRODUCTION APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an optical disc recording/reproduction apparatus and method and in particular, to an optical disc recording/reproduction apparatus and method capable of recording or reproducing a data to/from an optical disc with a high density.

2. Description of the Prior Art

In order to record or reproduce a data onto/from an optical disc with a high density, it is necessary to minimize the size of an optical spot applied to the optical disc. The size of an optical spot is known to be proportional to λ/NA assuming that λ is a wavelength of a light source and NA is a numerical aperture of an objective lens. Consequently, when the wavelength is constant, increase of the numerical aperture of the objective lens increases the possible recording density. The objective lens used as an aspherical single lens in a currently available optical disc apparatus is considered to have a numerical aperture of 0.6 at maximum because of the manufacturing reasons.

Moreover, as the numerical aperture increases, and as the thickness of the optical disc substrate increases, there will be more affects by the wave font aberration generated by the inclination or warp of the optical disc and assembly accuracy. For this, when using a lens having a large numerical aperture as an objective lens, it is necessary to reduce the thickness of the optical disc substrate. For example, according to the DVD (digital versatile disc) specification, the substrate thickness is defined as about 0.6 mm.

As an objective lens unit exceeding 0.6 of the numerical aperture, there is known a two-lens unit consisting of a solid immersion lens (SIL) and an objective lens which has been suggested by Kino and others (U.S. Pat. No. 5,125,750). With this two-lens unit, there is suggested an optical disc recording/reproduction optical system having the numerical aperture exceeding 0.8.

In this optical system, it is necessary to maintain a distance (air gap) between the SIL and the optical disc at an optimal value. If this air gap is greatly changed, a wave front aberration is generated, lowering the signal quality and, in the worst case, disabling to record or reproduce a data onto/from the optical disc.

In such an optical system using a two-lens unit, to maintain the air gap constant is equivalent to maintain constant a distance between the two lenses of the lens unit. If the distance between the two lenses of the two-lens unit is to be adjusted by an actuator to cope with a change in the thickness of the optical disc, a complicated configuration is required and it becomes difficult to assure an assembly accuracy.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a simple configuration using a two-lens unit capable of accurately recording or reproducing a data.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing a configuration example of an optical disc recording/reproduction apparatus according to the present invention.

FIG. 2 shows a detailed configuration example of an optical head unit of FIG. 1.

FIG. 3 explains a position of an optical spot.

FIG. 4 shows a detailed configuration example of a photo diode 33 of FIG. 2.

FIG. 5 explains a mounting state of an objective lens 27 and a forward lens 28 of FIG. 2.

FIG. 6, consisting of FIGS. 6A to 6C, explains the relationship between a lens size and a numerical aperture.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a block diagram showing a configuration of an optical disc recording/reproduction apparatus according to an embodiment of the present invention. Note that explanation will be given on the present embodiment for the case when a magneto-optical disc is used as the optical disc. The magneto-optical disc 1 is rotated by a spindle motor 2 at a predetermined velocity. An optical head unit 3 applies a laser beam and a magnetic field to the magneto-optical disc 1 for recording or reproducing a data onto/from the magneto-optical disc 1. A recording/reproduction circuit 4 modulates a recording signal supplied from a terminal 5, for supply to the modulated signal to the optical head unit, and demodulates a reproduction signal from the magneto-optical disc 1 outputted from the optical head unit 3, for output from the terminal 5.

A servo circuit 6 includes a focus servo circuit 11, a tracking servo circuit 12, a sled servo circuit 13, a spindle servo circuit 14, and an automatic power control (APC) circuit 15. The servo circuit 6 reproduces a predetermined error signal from a signal outputted from the optical head unit 3, so as to carry out a servo operation. That is, the focus servo circuit 11 generates a focus error signal from a signal outputted from the optical head unit 3, for example, according to astigmatism, so as to control the optical head unit 3 for focusing according to this focus error signal. The tracking servo circuit 12 generates a tracking error signal from a signal outputted from the optical head unit 3, for example, according to the differential push-pull (DPP) method disclosed in U.S. Pat. No. 4,775,968, and controls the optical head unit 3 for tracking according to this tracking error signal.

The sled servo circuit 13 generates a sled error signal from a DC component of the tracking error signal, and drives a sled motor 7 according to this sled error signal, so as to drive the optical head unit 3 in a predetermined radius position of the magneto-optical disc 1. The spindle servo circuit 14 generates a spindle error signal and drives the spindle motor according to this spindle error signal, so as to rotate the magneto-optical disc 1 at a predetermined velocity. The APC circuit 15 controls so that a built-in laser diode (which will be detailed later) of the optical head unit 3 emits a constant intensity of a laser beam.

A microcomputer 8 controls the respective components according to operation signals from an operation block 9 for carrying out recording or reproduction.

Description will now be directed to the operation of the microcomputer 8. When the operation block 9 is operated to issue an instruction for recording, the microcomputer 8 controls the respective components to start a recording operation. Firstly, the spindle servo circuit 14 of the servo circuit 6 drives the spindle motor 2 to rotate the magneto-optical disc at a predetermined velocity. The optical head unit 3 emits from the built-in laser diode a laser beam to the

magneto-optical disc 1 and receives a reflected beam so as to output a signal required for the focus servo and the tracking servo. The focus servo circuit 11 and the tracking servo circuit 12 generates from this signal a focus error signal and a tracking error signal, respectively, for controlling the optical head unit 3 for focusing or tracking.

On the other hand, a recording signal inputted from the terminal 5 is modulated in the recording/reproduction circuit 4 by a predetermined method and supplied to the optical head unit 3. The optical head unit 3 controls the laser diode according to the signal supplied. The optical head unit 3 has a magnetic head (which will be detailed later) which applies a magnetic field having a predetermined bias to the magneto-optical disc 1. As a result, a data is recorded on the magneto-optical disc 1 by a so-called magneto-optical effect. With this data recording, the sled servo circuit 13 controls the sled motor 7 so as to shift the position of the optical head unit 3 in a radius direction of the magneto-optical disc 1. Thus, a data is recorded on the magneto-optical disc 1.

On the other hand, when the operation block 9 is operated to issue an instruction for reproduction, the microcomputer 8 controls the respective components for starting a reproduction operation. The optical head unit 3 reproduces a data from the magneto-optical disc 1 and outputs a reproduction signal. The reproduction signal is supplied to the recording/reproduction circuit 4, where the signal is demodulated and outputted from the terminal 5. The APC circuit 15 monitors a laser beam applied to the magneto-optical disc 1 and controls so that a constant intensity of the laser beam is applied.

It should be noted that the other servo operations of the servo circuit 6 are identical to those of the recording mode.

FIG. 2 shows a detailed configuration of the optical head unit 3. The laser diode 21 emits a laser beam having a wavelength of 680 nm for example. A collimator lens 22 converts a divergent beam emitted from the laser diode 21, into a parallel beam. A grating 23 divides the laser beam from the collimator lens 22 into three laser beams. The laser beam emitted from the grating 23 enters a beam splitter 24 where a portion of the beam is reflected by a reflection plane 24A and introduced via a convex lens 25 to an APC photo detector 26.

Another portion of the laser beam which has passed through the reflection plane 24A is converged by an objective lens 27 and applied via a forward lens 28 to the magneto-optical disc 1. On the opposite side of the magneto-optical disc 1 where the laser beam is applied, the magnetic head 29 is arranged so as to apply a magnetic field having a predetermined bias.

The laser beam reflected from the magneto-optical disc 1 is returned via the forward lens 28 and the objective lens 27 to the beam splitter 24, where a portion (30% for example) of a p-polarized component and almost all of an s-polarized component are reflected by the reflection plane 24A and introduced into a beam splitter 30. After the laser beam has entered the beam splitter 30, a portion of the laser beam is reflected by a reflection plane 30A, converged by a convex lens 31, and given astigmatism by a cylindrical lens 32 before being introduced to a servo signal photo diode 33.

On the other hand, another portion of the laser beam which has passed through the reflection plane 30A is introduced via a half wave plate 34 for adjusting light quantity balance, to a polarization beam splitter 38.

From the laser beam which has entered the polarization beam splitter 38, a p-polarized component passes through a

reflection plane 38A and is converted by a convex lens 35 before being introduced via a concave lens 36 to a photo detector 37. Moreover, from the laser beam which has entered the polarization beam splitter 38, an s-polarized component is reflected by the reflection plane 38A and further by a reflection plane 38B and converged by a convex lens 39 before being introduced via a concave lens 40 to a photo detector 41. A difference between outputs of the photo detector 37 and the photo detector 41 is calculated by a differential amplifier 42 and is outputted as a reproduction magneto-optical signal.

During a reproduction mode, the laser beam emitted from the laser diode 21 and converted into a parallel beam by the collimator lens 22 is divided into three laser beams by the grating 23 and introduced via the beam splitter 24 to the objective lens 27. The laser beam converged by the objective lens 27 is applied via the forward lens 28 to the magneto-optical disc 1.

In this process, a portion of the laser beam to be applied to the magneto-optical disc is reflected by the reflection plane 24A of the beam splitter 24 and applied via the convex lens 25 to the photo detector 26. The APC circuit 15 of the servo circuit 6 controls power of the laser beam emitted from the laser diode 21 so that the output of the photo detector 26 is at a predetermined reference level.

As shown in FIG. 3, on the magneto-optical disc 1, a center laser beam of the three beams divided by the grating 23 forms an optical spot S1 on a groove (track) where a data is to be recorded or from where a data is to be reproduced, whereas laser beams arranged at right and left of the center beam form an optical spot S2 or S3 on lands positioned at right and left to the groove where the optical spot S1 is formed.

Beams reflected from the optical spots S1, S2, and S3 are introduced via the forward lens 28 and the objective lens 27 to the beam splitter 24, where the beams are reflected by the reflection plane 24A. The laser beam reflected by the reflection plane 24A is introduced into the beam splitter 30, where a portion of the beam is reflected by the reflection plane 30A. The laser beam which has been reflected by the reflection plane 30A is introduced via the convex lens 31 to the cylindrical lens 32 where it is given astigmatism and is introduced to the photo diode 33.

As shown in FIG. 4, the photo diode 33 consists of a photo diode 51 for receiving the beam reflected from the optical spot S1 and photo diodes 52 and 53 for receiving the beam reflected from the optical spot S2 or S3. The photo diode 51 is divided in the track direction (indicated by the arrow M) and in the vertical direction (indicated by the arrow N) to the track direction so as to form four regions A to D. The photo diodes 52 and 53 are respectively divided in the track direction so as to form two regions E and F, and G and H.

The focus servo circuit 11 calculates outputs from the regions A to D of the photo detector 51 according to an equation as follows, so as to generate a focus error signal F.

$$F=(A+C)-(B+D)$$

On the other hand, the tracking servo circuit 12 calculates outputs from the regions A to H of the photo diodes 51 to 53 according to an equation as follows, so as to generate a tracking error signal T.

$$T=(A+D)-(B+C)-k[(E-F)+(G-H)]$$

The servo circuit 6 controls an actuator (which will be detailed later) of the optical head unit 3 according to these